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# Quarterly Progress Report

*Division 7*

## Engineering

15 June 1964

Prepared under Electronic Systems Division Contract AF 19(628)-500 by

# Lincoln Laboratory

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Lexington, Massachusetts



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# Quarterly Progress Report

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*Division 7*

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Engineering

15 June 1964

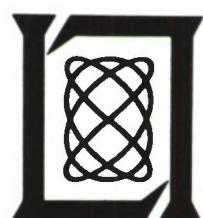
Issued 6 July 1964

Lincoln Laboratory

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Lexington, Massachusetts

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## INTRODUCTION

The Engineering Division provides mechanical, construction, and control engineering support to all Divisions of the Laboratory. In addition, it provides technical and physical plant services through its centralized shops. This report will summarize some of the principal engineering efforts during the quarterly period from 1 March to 31 May 1964.

Although the major effort presently under way is for the Haystack, PRESS, and Space Communications Programs, a continuing effort under the General Research Program concerns the mathematical analysis of paraboloidal shells and the development of computer programs and techniques for analyzing the large and accurately contoured antennas and supporting structures required in our research programs.

The Haystack Hill antenna has been completely assembled and its parabolic surface adjusted by North American Aviation Company in accordance with optical measurements taken after assembly. A continuing analysis is being made of measurement results for possible future adjustments. Meanwhile, system interconnections and the outfitting of radiometer and radar RF boxes are continuing.

Instrumentation of the KC-135 aircraft for the PRESS program has entered its third and final stage. The Phase II electronic equipment has been returned to the Laboratory for integration with the gimbal-mounted optical instruments in the mock-up here at the Laboratory, while the aircraft is being modified at Schenectady to receive all this gear. Calibration and handling equipment are being designed and fabricated as well.

Two major efforts under the Space Communications Program are the experimental research satellite and the experimental terminal. Mechanical design, fabrication, and testing of the satellite structure, together with its support and ejection mechanisms, are proceeding on schedule.

Additional tasks for the Apollo, AMRAD, and Re-entry Physics Programs are detailed.

15 June 1964

J. F. Hutzenlaub  
Division Head

Accepted for the Air Force  
Franklin C. Hudson, Deputy Chief  
Air Force Lincoln Laboratory Office

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# REPORTS BY AUTHORS IN DIVISION 7

15 July 1963 through 15 June 1964

## PUBLISHED REPORTS

		<u>Technical Report</u>		<u>DDC and Hayden Nos.</u>
TR No.				
328	Haystack Antenna System Status Report	A. O. Kuhnel	13 September 1963	DDC* H-583
<u>Group Reports</u>				
No.				
71G-1-III	Distortions and Stresses of Paraboloidal Surface Structures, Part III	J. W. Mar F. Y. M. Wan	15 August 1963	DDC 417081 H-535
71G-1-IV	Distortions and Stresses of Paraboloidal Surface Structures, Part IV	J. W. Mar F. Y. M. Wan	29 April 1964	DDC 600125 H-579
1964-19	Analog Orbit Computer	N. P. Smith S. H. Wright	16 April 1964	DDC* H-583
<u>Journal Articles†</u>				
JA No.				
2061A	Cryogenics for the Electronics Engineer	J. W. Meyer‡ A. M. Rich	Electronics <u>36</u> , No. 35 (1963)	
2183	Some Physical Properties of Nonlinear Elastic Suspensions as Analyzed by the Averaging Method of Ritz	E. Jozefowicz	Machine Design <u>35</u> , 169 (24 October 1963)	

## UNPUBLISHED REPORTS

<u>Meeting Speeches§</u>			
MS-956	Discussion of Papers Presented at Large Steerable Radio Antennas Conference	P. L. E. Alberti	Proc. Conference on Large Steerable Radio Antennas, New York, 4-6 September 1963
MS-1069	A Look at Gear Application Requirements for Future Steerable Antennas	P. L. E. Alberti	Aerospace Gearing Committee, Orlando, Florida, 29 February 1964

\* Not yet assigned.

† Reprints available.

‡ Division 3.

§ Titles of Meeting Speeches are listed for information only. No copies are available for distribution.

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# MECHANICAL ENGINEERING

## GROUP 71

### I. GENERAL

Group 71 is responsible for the mechanical engineering and design aspects of all Laboratory programs. At present, the major tasks are for the Haystack project, as well as the Re-entry Physics, PRESS, and Space Communications Programs. On-site mechanical engineering support and accompanying design work continue for the Radar Discrimination Technology Program.

The engineering and design tasks for the Haystack project are presented in the Group 76 section of this report.

### II. LABORATORY SERVICES

Evaluation of closed-cycle refrigerators for use with operational systems continued during this reporting period. The Arthur D. Little, Incorporated, cryodyne, which had failed under test, was extensively overhauled. Evaluation testing of the repaired unit resumed on 7 May 1964. At the present time, the system is operating satisfactorily, maintaining a temperature of 4.2°K with a 600-mw electrical load at the cold station. The total number of hours of continuous operation without failure at this time is 239.

A unit from a second supplier, Malaker Laboratories, was received and evaluation testing started on 1 May 1964. This unit operates on 400-cps power and is applicable for mobile installations. The unit cooled down in 30 minutes to 24.5°K. This temperature is in the operational range for parametric amplifier applications. After 36 hours of operation, the temperature of the unit started to deteriorate and the manufacturer requested that the unit be returned to the factory for inspection.

### III. GENERAL RESEARCH

Structures research has continued on the paraboloidal shell analysis and on the improvement and development of computer programs for framed structures.

#### A. Paraboloidal Shell Analysis

Part IV of Group Report 71G-1, "Distortion and Stresses of Paraboloidal Surface Structures," has been distributed. This report uses asymptotic integration methods to obtain solutions for shells which are deeper than those treated in Part III. A large number of specific configurations have been analyzed and the numerical results are presented in the form of dimensionless plots. The discussion is focused on the deformation behavior under gravity loads as it is affected by the span of the shell, the direction of the gravity vector, and the boundary conditions. There are also contour plots of deflections relative to the face-up position which depict the change in the shape of the paraboloidal surface as the direction of the gravity vector is changed.

Part V is approximately 25-percent complete and will be a user's manual for the computer programs developed in Parts I through IV. Preliminary work is proceeding on the study of shell behavior under both loads and distortions applied at the edges.

### B. Improvement and Development of Structural Analysis Computer Programs

Three main programs are involved in this effort. These programs are STAIR (structural analysis interpretive routine), FRAN (frame analysis), and a new lattice analogy program for the analysis of shells.

STAIR:— The "ill-conditioning" detection and improved inversion routines are in a final debugging stage.

FRAN:— The equilibrium check has been completed and is working successfully.

Shells:— The program for this analysis has been written and is now being tried on test cases. It is not actually running at this time.

## IV. RE-ENTRY PHYSICS

### A. 48-Inch Spectrometric Telescope

#### 1. Tracker Redesign

The new tracking head which will replace the present 48-inch tracking head (fine tracker) and completely eliminate the use of the 12-inch tracking telescope (course tracker) has been designed and is now being detailed.

When manufactured, the tracker will undergo extensive bench testing before installation on the 48-inch telescope.

#### 2. Camera Mount

A camera mount for use in the optics laboratory is being designed to utilize a Celeostat mount now in existence. The mount will accommodate up to three K-39 cameras or other cameras of various sizes. The drives will be modified to give greater versatility in both the polar and declination axes.

#### 3. Encoder Installation

Sixteen-digit angular Baldwin encoders have been installed in both the azimuth and elevation axes of the telescope mount. The angular deflection of the elevation encoder drive shaft, including the coupling, is of the order of ten seconds of arc. The angular deflection of the azimuth encoder drive shaft is of the order of two minutes of arc. The large error in the azimuth axis is the result of using the thin-wall hydraulic rotary joint tube as a drive shaft. The azimuth installation is considered temporary and will be replaced. It is planned to eliminate the azimuth hydraulic rotary joint by placing the hydraulic supply system on the mount. This will make it possible to install a stiff shaft on the azimuth axis to drive the encoder with an angular deflection of about 10 seconds of arc.

### B. Trailblazer II Optical Experiment

Design of the optical payload is virtually complete. Minor modification to accommodate the electronic packaging is contemplated. All major components have been fabricated and are ready for assembly. A prototype model of the payload was partially assembled and environmentally tested to check the drum recorder and commutator. A subassembly of the optical system has successfully undergone environmental testing.

The heat shield, with a simulated weight and inertia payload mounted on the third- to fourth-stage truss adapter, has undergone environmental tests to determine the magnification factors transmitted through the truss adapter.

## V. PRESS PROGRAM

### A. KC-135 Airborne Instrumentation

#### 1. General Arrangement – Phase III

During this reporting period, the KC-135 was engaged in down-range operations for the purpose of checking out the Phase II equipment which consists of the airborne optics control system, the modified Skyscraper, and a manual acquisition device. Meanwhile, at the Laboratory, design and construction continued on the instrument mounts, associated electronic systems, and calibration equipment. The aircraft returned from downrange on 19 May 1964, at which time the project equipment was returned to the mock-up for final system integration and test while the aircraft undergoes the Phase III modification, which includes removal of the refueling boom, installation of additional jacking points, installation of additional communication and navigation equipment, and installation of the instrument mount foundations. The Phase III installation is expected to be complete in early September.

#### 2. Instrument Mounts

Assembly of the aft instrument mount array is well under way. Individual mounts have been completely assembled, with the exception of the lead screw drives which were delivered from the vendor in late May. Wiring of the Orthicon and Tracker/ARS mounts is 90-percent complete. The experience gained on the complex cable harnesses required for these two mounts should make the wiring of the METES instruments and Cinespectrographs much more straightforward. The translating base has been assembled and aligned in the machine shop and is ready for the installation of the trucks. The trucks and base pads have been temporarily aligned in the mock-up, and alignment tooling has been fabricated which will be shipped to the General Electric Company for preparation of the mounting holes in the aircraft.

The design of the forward mount (long focal length camera) is proceeding and the gimbal rings have been released for manufacture. Because of a delay in the design schedule, this mount will not be available for installation at Schenectady. However, tooling is being prepared so that final attachment points can be installed in the aircraft at Schenectady. This will permit minimum downtime during field installation in November.

#### 3. Electronic Equipment

Design integration of the electronic subsystems is nearly complete. The last major vendor-supplied equipment was delivered in late May, and is being installed in the mock-up. All new electronic racks for Phase III are expected to be complete by mid-June. The remaining major design problem appears to be the cabling of the instrument mount assembly. Some modifications (equipment relocations and wiring harness rerouting) will be required on the Phase II equipment and will be accomplished in the mock-up during the month of June.

## GROUP 71

### 4. Aircraft Modification

The additional Phase III modification requirements were issued to General Electric in mid-April. Design and manufacture is proceeding on these items as well as on the items in the original specification. The gating task will be the instrument mount foundations and instrument mount installation. The contractor has built a fixture which will be used to assemble and align the 20-foot-long 3500-pound mount support structure in his shop prior to installation in the aircraft. In the absence of the forward mount, Lincoln Laboratory will furnish a drilling template which will be used for spot mounting holes in the aircraft and for locating the mating holes in the instrument mount when it is completed. In this way, we expect to accomplish a field installation in one week.

The aircraft modification design appears to be on schedule and no known problems exist at this time.

### 5. Calibration Van

Design studies have been completed for the installation of the 14-inch calibrator electronics as well as for the METES calibrator electronics in the calibration van; this will require removal of the existing work bench.

### 6. Calibrator Attachment Brackets

Preliminary design layouts have been prepared for brackets that will attach the calibrators, weighing approximately 350 pounds each, to the aircraft window frames.

### 7. Staging

A service platform or staging is required both at Hickam Field in Hawaii and at Wake Island for access to the aircraft windows for cover removal, window washing, attachment of calibrator brackets, etc. Procurement specifications have been prepared and sent out on RFI for this staging, which will consist of a central tower supported on splayed legs, and carry a cantilevered bridge extending some 30 feet over the aircraft wing.

### 8. Aerial Lift

Proposals have been received for an aerial lift capable of lifting an operator and a calibration collimator from the ground to each of the aircraft window stations.

The lift, mounted on a standard truck chassis, would be powered from the truck transmission and would be capable of being controlled from either the personnel basket or from the ground. Selection of a vendor and award of a contract will be accomplished in early June 1964.

## B. Collimator for the Multi-Element Total Event Spectrometer (METES)

The collimator has been completely detailed and is now being checked. Release for manufacture will follow final review of the complete optical system as well as the arrangement for mounting the unit to the aircraft.

The collimator will be mounted successively on the external side of each KC-135 aircraft window, facing the METES spectrometers, and will be used to calibrate the instruments before and after each mission.

### C. Laboratory Collimator

The expanded Laboratory model of the METES calibrator is now being aligned optically and will be used to calibrate the two METES spectrometers.

### D. METES Spectrometers

The far-infrared spectrometer has been completely assembled and awaits the completion of the Laboratory collimator for final adjustment of the optical system.

The assembly of the ultraviolet and near-infrared spectrometer will be completed shortly. Final adjustments will be made with the Laboratory collimator.

### E. Recording and Optical Tracking Instrument (ROTI)

The ROTI instrument located on the island of Roi-Namur, Marshall Islands, had been producing erratic and inferior photographic data. An engineering service team from Groups 71 and 76 therefore performed a complete electromechanical inspection and maintenance program.

The elevation gear train was completely disassembled for inspection, cleaned and realigned for proper tooth clearance. The gear-train housings were modified to include access ports to provide for gear-mesh inspection and proper lubrication. A "Boroscope" and camera technique was used at final assembly through the gear mesh inspection ports to inspect for gear-mesh clearance and gear-tooth interference.

The azimuth gear train was inspected and the backlash measurements of 0.002 to 0.006 inch between the pinion and ring gear were found to be within the Navy specifications for this form of gearing. A lubrication specification and schedule were added to the maintenance manual for the elevation and azimuth gear systems.

A "basket" counterweight unit was installed to maintain a "nose heavy" center-of-gravity condition ahead of the trunnion center line, thus greatly improving the drive control and pointing performance.

Measurements of the flatness and level of the azimuth bearing relative to the azimuth platform showed it to be flat but tilted by 0.0005 radian.

Tracking and photographic performance tests were conducted by using manual control and TRADEX computer control, with most satisfactory results.

## VI. SPACE COMMUNICATIONS

### A. Lincoln Experimental Satellite (LES)

Design of the satellite and its booster assembly is approximately 50-percent complete. Manpower buildup was late and has caused us to reduce the time allocated for test and qualification. Mechanical fabrication is on schedule.

#### 1. Satellite Structure

The frame, hub casting, and tooling designs for the satellite structure have been completed. Two additional assembly fixtures are being fabricated to improve the delivery schedule for machining and inspection. Machining of the first flight frame will start during the first week of June. Prototype assembly of the first satellite frame for design proof testing is scheduled to start 1 July 1964.

## GROUP 71

### 2. Solar and Antenna Panels

Design of the solar-panel honeycomb substrates has been completed and the first panel has been fabricated. These are  $\frac{1}{8}$ -inch-thick aluminum honeycomb sandwich panels with 0.005-inch-thick skins and with extruded aluminum edges. The stiff edges overlap from panel to panel and are bolted at assembly, together with a silicone material between the edges to provide thermal contact from panel to panel. To improve the thermal radiation properties of the panels, the inside of each panel will be painted black and the outside will be fitted with aluminized glass reflector segments in those areas not covered by solar cells. An electrical connector is being added to these panels to provide reliable wiring connections.

Magnetic field studies showed that the exterior surface of the satellite would have to be interrupted by insulated barriers if the satellite spin rate were to continue for any length of time. To accomplish this, the honeycomb surface plates were insulated from the edge extrusions by adding a primer and selecting an epoxy that would electrically insulate the two surfaces.

### 3. X-Band Horn Antennas and RF Switches

The X-band antennas are mounted in the center of each triangular panel (8 total) with the axis normal to the panel. The antenna is a hollow aluminum cylinder filled with tellite, a dielectric material. Fabrication of the first set is expected to be complete by 1 July 1964.

The solid state X-band switches, consisting of 2 single-pole 4-throw switches and 1 single-pole 2-throw switch, are being lengthened to reduce the attenuation between the X-band components in the satellite.

Six telemetry antennas are located on the antenna panels such that they describe an approximate circle about the satellite. Each antenna is a folded monopole which protrudes  $1\frac{1}{4}$ -inches from the antenna panel. Fabrication of the first set is expected to be complete by 1 July 1964.

### 4. Spin Table

A prototype model spin table has been built and is ready for testing. The prototype version is slightly smaller in diameter than the flight model but is otherwise identical. The model will be used to determine the feasibility of the system and the separation parameters under ambient conditions. It will also be used to calibrate the energy of the system through the expected flight temperature range. Design of the flight version has been completed and is being prepared for release.

### 5. Rocket Support

The present rocket motor has a thrust misalignment of 35 minutes of arc relative to the mounting axis. The large misalignment would require a high spin rate to maintain stabilization during powered flight. This problem will be minimized by addition of a tailored adapter fitting on the rocket-motor mounting flanges. This adapter will be machined to provide alignment of the mounting axis with the rocket nozzle axis (thrust axis) with 10 minutes of arc. A spin rate of 180 rpm will then provide a margin for stability during powered flight and also a margin below 200 rpm, the maximum allowable spin rate of the rocket motor.

#### 6. Satellite Support

Design of the satellite support and ejection system has been completed and fabrication is under way. The system consists of four ball and collet assemblies retained by a V-band coupling. A ball end stud is inserted into each of the four bottom hub castings of the satellite and mates with a collet. The four collets are actuated by a common flange which is retained by a V-band coupling. The V-band coupling is released by two explosive actuators either of which will release the coupling. Alternate techniques for supporting the satellite are being investigated. One system consists of the previously described four ball end stud and collet units individually supported and released by an explosive actuator.

#### 7. Satellite Vibration Tests

During the past quarter, a 25-pound dummy satellite was subjected to new vibration test specifications required by the Titan III vehicle. This consisted of random vibration levels higher than the originally used Atlas-Agena random specification, and included a combined "random-plus-sine" test. In March, tests were conducted during which the satellite was subjected to the following vertical vibration inputs:

- (a) Resonance sweep search (5 to 2000 cps) at 3 g
- (b) Random A (shaped) at an over-all 16.4 rms level
- (c) Random B (shaped) + sine at an over-all 13.8-g rms level.

During these tests, acceleration levels at various locations in the satellite were monitored as well as the strains on 20 members. Highest acceleration observed was a 254-g peak during the combined random B-sine test, while during the same test, the highest observed stress of 35,000 psi occurred on member No. 20. The satellite was fully panelled with simulated solar panels and simulated double instrument shelves. Vibration inputs were applied directly to the base of the satellite frame. During the same period, the above three tests were also applied in a horizontal direction to the satellite base. Results of these tests are currently under analysis. Future tests, to be made in the next quarter, will include the same vertical and horizontal vibration tests, but with an attached steel casing about 32 inches high and weighing 175 pounds, to simulate the rocket motor, spin mechanisms, and housing assemblies. Vibration inputs will be to the base of this casing, with the satellite attached at its top - an over-all assembly height of about 60 feet. Comparisons will be made between these tests to evaluate the vibration transmission properties of the satellite's lower assemblies.

#### 8. Satellite Test Program

The general plan of the program is to perform functional tests on each component, sub-assembly, and final assembly. This is to be followed by performance tests under simulated environmental conditions. Two test levels are contemplated: proof model testing at 120 percent of specified requirements, and flight model testing at 80 percent of specified requirements.

One of the first tests planned is the simulator test on the spin and ejection mechanisms. The purpose of the test is twofold: (1) to determine the behavior of a weight-and-inertial simulated model of the satellite during spin-up and ejection; (2) to determine the performance of the

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spin-up and ejection mechanism. The first series of tests will use high-speed photography to produce qualitative results. The second series will produce qualitative results with high-speed photography as well as other instrumentation such as accelerometers and potentiometers. A third series will be the temperature calibration tests on the spin and ejection mechanisms. The mechanisms will be subjected to temperature environments ranging from  $-40^{\circ}$  to  $+160^{\circ}$ F and, at each temperature selected, the performance of the mechanism and behavior of the model will be monitored with the instrumentation noted.

Complete detailed test planning is in progress and should be ready for approval by the first week in June 1964.

### 9. Analytical Evaluation

Analytical evaluation of the preliminary design is approximately 80-percent complete. Stability during rocket firing, load and bending moment distribution, dynamic load factor, de-spin mechanism, satellite ejection mechanism, satellite ejection structure, spin-up and push-off mechanism, Marman clamp, and booster motor-support analysis are completed. Detailed equipment installation and frame and solar panel attachment analyses are continuing.

### 10. Operations

A proposal by Martin-Marietta Company to provide the interface between our scientific payload and the Titan III launch vehicle is being negotiated. Communications between Lincoln Laboratory and the Martin-Marietta Company will be established through the USAF Space Systems Division.

Ordnance items have been discussed with Franklin Institute and the USAF representatives of range safety at Patrick Air Force Base.

Final assembly and spin balance have been discussed with the USAF representatives at Patrick Air Force Base, and the existing Blue Scout facilities at Cape Kennedy were assigned to accommodate our payload.

## B. Lincoln Experimental Terminal (LET)

### 1. Prime Mover

A four-wheel-drive truck-tractor has been ordered as the prime mover of the terminal. This tractor has sufficient draw-bar pull to haul the electronics van semi-trailer (gross weight 24,000 pounds) plus the antenna vehicle full-trailer (gross weight 18,000 pounds) at speeds up to 34 mph on paved roads and can negotiate 40-percent grades with full load in lowest gear, operating at altitudes to 6000 feet above sea level. Delivery of this unit is expected in July 1964.

### 2. Electronics Van

Delivery of this vehicle is scheduled for June. Most of the modifications to the interior of the electronics van have been designed and the equipment has been ordered. The gas-turbine alternator and the air conditioner unit are scheduled for delivery during the latter part of June. Quotations have been requested for the modifications to the electronics van interior.

### 3. Antenna Vehicle

Design of the main structure of the antenna pedestal is about 75-percent complete, and quotations have been requested for the elevation and azimuth drives. Most small items such as drive motors, bearings, hydraulic buffers, brakes, etc., have been ordered and some of these have already been received. Quotations have been received for the running gear and undercarriage of the antenna vehicle and the order will be placed shortly. Fabrication of the antenna is nearly complete and delivery is scheduled for the latter part of June 1964.

### C. Analog Orbit Computer

The analog orbit computer located at the West Ford communications site is now in operation and data testing. Preliminary reports indicate that results are as anticipated. Three additional gear boxes for latitude correction, Doppler frequency, and mean anomaly correction have been designed and manufactured. These units provide necessary information for data refinement.

A new analog orbit computer, a more compact version of the West Ford unit, is now being designed to be incorporated in the Lincoln Experimental Terminal electronics van. The variable speed drive used in the first computer has been redesigned and is now being manufactured by Astro Gear and Instrument Company. Preliminary designs for approximately 10 other gear boxes have been completed. A single readout unit will be used for this computer. By means of various switch gear, all gear boxes may be monitored through one precise readout and control unit.

## VII. RADAR DISCRIMINATION TECHNOLOGY

### A. AMRAD Equilibrators

The frequency of equilibrator bearing failures has plagued both AMRAD and Rampart sites since they were built. Investigation of the equilibrator problem reveals that the design of the self-aligning bushings is totally inadequate for this application. The metallurgy and configuration of this bushing result in a low impact strength design of 30,000 to 35,000 psi. Since normal bearing loads reach 35,000 psi in this system and higher with impact, load failures have occurred at the two-piece race of the bushing. However, this bushing configuration with design changes as noted will meet the requirements of the equilibrator application with ample safety margin.

The material to be used in the race and ball should be high-impact-strength steel, E-3310. With appropriate heat treatment, high impact strength and good wear characteristics should be developed. Impact strength will be well over 150,000 psi.

Other design changes include a one-piece race with a loading slot for inserting the ball. A one-piece race will have hoop strength, symmetry, and a continuous running surface for the ball. Lubrication for this bearing will consist of Molykote "G" grease to be applied at regular intervals. This lubricant meets the extreme pressure requirements of the bushing.

### B. Lubrication

A program of relubrication of all rotating machinery was initiated. Most of the items had not been lubricated since installation, and on many it was necessary to install  $\frac{1}{8}$ -inch piping in order to reach the fitting. Since normal operation had to be carried on, the period of lubrication extended over many weeks, but has finally been completed. A major delay in this program was

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the lubrication of the inner bearings on the magnetic clutches. Two clutches could not be lubricated and finally had to be removed from the azimuth drive system. Their removal provided an opportunity for rebuilding these two clutches, installing new bearings, cleaning, and resealing them.

## VIII. APOLLO

The vendor for the Cassegrainian telescope which is to be used as the receiver has been selected and delivery of the unit is scheduled for the first part of June.

Design of a transmitter has been started and fabrication is following along with the design. The mirror mount and associated support equipment is currently being fabricated. The design of a dewar for mounting the diode on the receiving telescope is approximately 80-percent complete.

Both the transmitter and receiver are to be mounted on a Nike-Ajax modified mount which will house the Model 2 Apollo optical radar.

# CONSTRUCTION ENGINEERING

## GROUP 75

### I. GENERAL

Group 75 provides the Laboratory with in-house consulting engineering services in the civil, structural, electrical, heating, ventilating, and air conditioning fields. During the last quarter, the group has applied considerable effort to the further development of Haystack Hill, and this work is included in the Group 76 section of this report.

### II. CONSTRUCTION

#### A. Storage Building, Millstone Hill

The Millstone Hill storage building which was constructed during the winter months is now complete. This building is a prefabricated metal structure, 60 × 122 feet, with an eave height of 14 ft. 0 in. A 3000-pound capacity electric hoist was installed on a monorail to assist in the handling of material.

#### B. Boiler Room, Millstone Hill

Phase I of the Millstone Hill boiler room addition has been completed. This work consists of a new metal structure, 24 × 40 feet in plan, which houses the 80-hp steam boiler and the two emergency generators. A 10,000-gallon fuel-oil tank and associated piping were also installed. The new 80-hp steam boiler has been purchased and is in place, but the necessary piping has not yet been installed.

#### C. Radar Transmitter Research Facility, Lexington Field Station

The radar transmitter research facility was completed during this quarter. This facility consists of a metal building 60 × 142 feet with a 28-foot eave height. A 5-ton bridge crane with a 21-foot hook height services the entire floor area. A cooling water manifold is located on two sides of the building, with valve stations for local distribution of chilled water. The liquid cooling system has a heat dissipation capacity of 2250 kw-hr and is expandable to 3000 kw-hr. In addition, the mechanical ventilating system will exhaust 56,000 cubic feet of air per minute.

### III. ENGINEERING

#### A. Re-entry Simulating Range Addition, Lexington Field Station

The plans and specifications for the addition to the Re-entry Simulating Range will be completed and bids received by 1 July. This addition will increase the existing facility by 4300 square feet. The space will be utilized for the extension of the two existing ballistic tunnels, a new laboratory, enlargement of the existing boiler room and new storage space.

#### B. Surveys

Several optical surveys and investigations were conducted during this quarter. The configuration of the 200-foot zenith pointing antenna at Millstone Hill was checked. This survey is

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conducted annually to check the antenna surface and supporting structure for any irregularities that may have occurred during the winter season. A continuing survey is being conducted at the Re-entry Simulating Range to determine what is causing the peculiar behavior of the structure and equipment. A first-order orientation survey was conducted to determine the geodetic position of the lunar radar that is located on Building D. This was done by using a geodometer in conjunction with standard optical geodetic equipment.

### C. Structural Analysis of Building D Floor Framing Members

An analysis of the floor in Room D-224 was made, using the JPL computer program. This general-purpose program is capable of analyzing structural systems such as small space frames, trusses, and (in this case) grids. The input data for this run may be partially reused for the analyses of special loadings in similar areas of the Laboratory buildings.

This analysis confirmed previous hand computations which indicated that 75 pounds per square foot is the safe live load on these typical upper floors, instead of 125 per square foot as shown on the contract drawings.

# CONTROL SYSTEMS

## GROUP 76

### I. OBJECTIVES

Group 76 is responsible for the design and development of control systems for various Laboratory programs. The equipment consists primarily of automatic controls involving servo-mechanisms and computers.

### II. GENERAL RESEARCH

Studies were conducted to determine the required compensation techniques for optimum pointing performance of the Millstone radar antenna after the torque bias antibacklash system is installed. Necessary components for this system are on order, and installation is expected to begin during the next quarter. Design work on improved data gear boxes for the Millstone antenna was started.

Evaluation of the prototype digital-to-analog converter for use in closed-loop systems was continued. A complete report on the theoretical work and circuit development associated with this project will be submitted shortly. This converter will be used in the pointing system for the LET terminal.

During this period, a general-purpose analog computer was acquired for use in the analysis, synthesis, and simulation of complex structures and automatic control systems. This machine has a designed repetition-rate capability of 20,000 solutions per second with a maximum phase shift of one degree at this repetition rate. Preliminary tests conducted by vendor personnel to align and verify machine performance were monitored. It is expected that final acceptance tests of the basic computer will be completed by 1 July 1964.

### III. SPACE COMMUNICATIONS

Preparations were completed for replacing the existing hydraulic drives on the West Ford Millstone mount with Ward-Leonard electric drives. It is expected that the site will be shut down while this change is in progress, effective 20 June 1964.

Work continued on defining the interface between the general-purpose digital computer to be used for orbit computations in the LET and the antenna control system. Group 76 will furnish equipment for the complete analog closed-loop system, plus the equipment necessary to receive and utilize digital pointing information from the computer. Design work was started on power wiring, switching, and control system interconnection for the LET terminal.

An improved analog orbit computer was proposed for use at the Camp Parks West Ford terminal. Tests of the existing computer at the Millstone West Ford site indicated that observed computer accuracies are near those calculated from individual accuracies of the several components used in the computation. Group Report 1964-19, describing test results and the proposed improved computer, was prepared for publication.

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### IV. PRESS

The ROT1 camera mount at Roi-Namur in the Kwajalein atoll was modified by installation of potentiometric-takeoff joysticks for azimuth and elevation control. These replaced capacitive-takeoff joysticks having unacceptable drift rates. Performance was improved further by the mechanical alignment of azimuth and elevation power gearing by Group 71 personnel. After modifications and adjustments were completed, the camera was operated against an aircraft target. The resulting film was described as excellent.

The command servo assembly for the PRESS KC-135 aircraft was received from the vendor. Acceptance tests as listed in the procurement specification were performed. All errors were well within the prescribed limits.

### V. AMRAD

A Mark 51 optical director was installed at the White Sands, New Mexico, AMRAD site as an AMRAD acquisition aid. Remote indication of the AMRAD acquisition radar (AGAVE) pointing angles was provided by the installation of digital shaft encoders on the existing antenna position repeater unit.

### VI. APOLLO

Tests were completed on the telescope mount intended for lunar reflectivity studies. Performance of the mount power drives was generally satisfactory. Minor modifications necessary to provide a faster position-correction capability were made.

## VII. HAYSTACK HILL EXPERIMENTAL FACILITY

### A. Lincoln Laboratory Activity

#### 1. Antenna Equipment Boxes

##### a. RF Box (Radar)

RF Plumbing and Electronics:- The layout and design of the 7750-Mcps transmitter were completed and released for manufacture. Large items such as equipment racks, cooling fans, klystron, klystron support, and up-converter have been received and are being installed. Work is continuing to find a satisfactory arc detector.

The various support structures for the arithmetic network and receiver dewars have been completed and are ready for installation.

Cryogenics for Low-Noise Receivers:- The closed-cycle cryogenic refrigerator, which will be used to cool eight parametric amplifiers, was received. During initial operation of the system, a helium line malfunction was discovered after 79 hours of operation. The manufacturer requested the return of this unit and repaired the line. Metal fatigue was considered to be the probable cause of failure.

A second system (No. 2) was also completed. Test at the manufacturer's facility on 23 April 1964 showed that No. 2 system functioned as anticipated, and cooldown to 3.8°K from ambient was accomplished in three hours and fifteen minutes. Several different electrical loads were applied to simulate the actual electrical loading during operation. The system maintained

a 1000-mw load at 4.2°K. On 4 May, the unit was started at Lincoln Laboratory where it operated until 8 May. No. 2 system was then shut down to make modifications to the cryostat and for installation of an accelerometer on the parametric amplifier structure for vibration measurement. The total number of hours to date on the No. 2 unit is 182.

The backup program of batch-filled dewars has progressed to the point where the amplifier headers have been constructed. The dewars for this system have had valves installed to improve the hold time for system use.

Structural Design:- The mechanical design of the radar box is complete. Additional design and fabrication tasks in support of component mounting and holding are being conducted. Fabrication progressed to the point where the box was released for RF and electrical component installation on 25 May 1964.

b. Radiometer RF Box

Structural Design and Fabrication:- The radiometer box was released for RF component installation and was installed at the Haystack site cornucopia test dock during the week of 25 May 1964. Design and fabrication tasks supporting component installation problems continue. A test program was concluded at the antenna test range which included measurement of cornucopia antenna pattern, gain, and RF axis location. RF operation will initially be at  $K_U$ - and  $K_L$ -bands.

c. Test Dock No. 2 (Cornucopia Dock)

Fabrication and installation work on the cornucopia antenna and east-west axis pedestal has been completed at Haystack (Figs. 76-1 and 76-2).

The pedestal control cabling from the control room to the cornucopia cable terminus building has been installed and terminated. Dual controls exist in the main control room and in the radiometer box.

d. Test Dock No. 1

The Conti and Donahue Corporation of Lynn, Massachusetts, has been awarded a contract for the fabrication, construction, and installation of the complete indoor test dock facility. Work is tentatively scheduled to get under way at the site on or about 1 July 1964.

A temporary dock was set up at the Millstone facility for the purpose of weighing and balancing the radiometer box. This capability will be included in Test Dock No. 1.

2. System Interconnection

a. Control Room

The patch panel console has 75 percent of its cable installed and terminated. The remaining cables will be installed and terminated by 15 July 1964. Subsystem cables which have been installed are in the process of being terminated.

Installation of all cable-handling equipment in the control room has been completed.

Cable routing drawings for the control room equipment cabinets describing all subsystem wiring has been completed.

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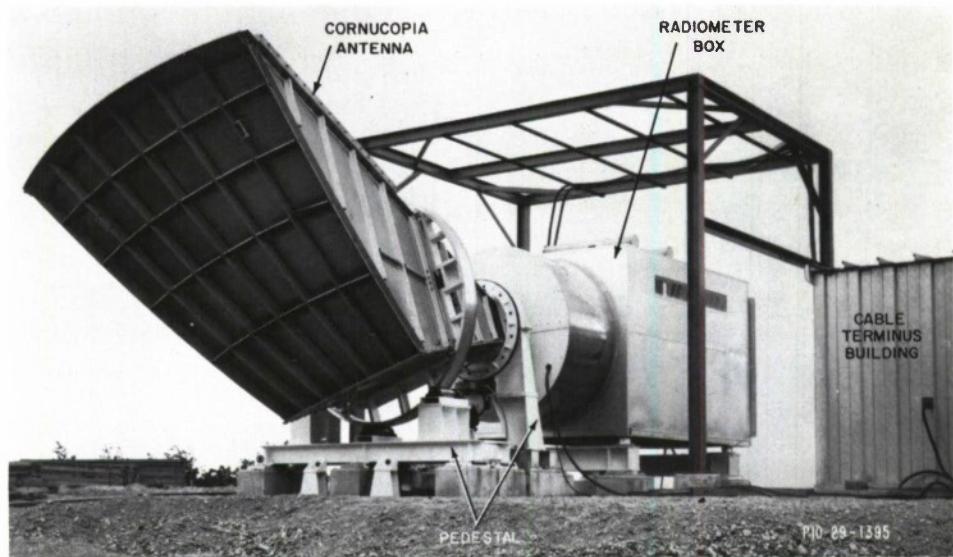


Fig. 76-1. Test derrick No. 2, antenna in operating attitude.



Fig. 76-2. Radiometer box and cornucopia assembly, antenna in stowed position.

b. Antenna

Cabling has proceeded to the point where all the M.I.T.-LL cables have been routed throughout the antenna and termination of the cables at two junction box levels has been completed. The third level termination is in progress.

c. Distilled Water Pipe Lines

The distilled water pipe lines from the base of the tower to the quick disconnects at the RF box have been installed, cleaned, and tested. Connection of these pipes to the pipes coming from the pump room will be made when the pump room equipment is ready.

3. Site Construction

During this quarter, the Construction Engineering Group has been occupied in the preparation of plans and specifications for projects scheduled for construction during the next two quarters.

Effort has continued on relocation of a primary substation, security fencing, a fuel oil tank installation, an intersite cable tray, the cornucopia test dock, Test Dock No. 1, transmitter cooling, regulated and unregulated power distribution, radome heating, and a boiler room addition.

a. Site Development

Plans and specifications for the Haystack site development work have been completed, proposals received, and construction started. This includes the paving of the access roadway from the site, local paving around the facility, construction of a parking area, miscellaneous drainage structures, security fencing, loaming and seeding of certain areas. This work should be completed before the end of the next quarter.

b. Radome Heating and Boiler Room Extension

Plans and specifications for the installation of a 12,600-gallon fuel oil tank and a substation pad have been prepared and construction started.

Plans and specifications for the radome heating system and boiler room extension are now complete and are in the bid stage. The entire system should be in operation for the 1964-1965 heating season. The boiler plant consists of two 125-hp hot water boilers capable of producing 8,368,800 Btu/hr and one 80-hp steam boiler. Heat is supplied to the radome via thirty thermostatically controlled hot water heating units.

c. Miscellaneous

The foundation pad, overhead steel structure, and the cable terminal building construction for the cornucopia test dock have been completed.

The intersite cable tray that runs from the Millstone Hill site to Haystack Hill is now under construction. This structure consists of an 18-inch-wide tray supported on steel stanchions. The tray was designed to meet the environmental conditions of the area, including thermal expansion and electrical discharge from the atmosphere. This work should be completed before the end of the next quarter.

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Test Dock No. 1 is located in the area under the radome that abuts the control and high-voltage rooms. The plans and specification for this work have been completed and the purchase order has been awarded.

### 4. Antenna Structural Analysis

The IBM-FRAN (frame analysis) computer program has completed an initial solution. This solution has been compared with the Phase II antenna full-scale reflector static test program. The FRAN program is being refined to incorporate these experimental results, and will be used next to check the present reflector rigging tables.

### 5. Haystack Radome

During the past quarter, work has begun on the application of strain gages to approximately 30 beam members of the Haystack radome for load analysis under wind loading. Strain-gaged members generally lie along two vertical great-circle arcs of the radome. Extra members are located completely around the equator level and at the base level. All members lie in either vertical (great circle) or horizontal planes. Each member is gaged with three full bridges to monitor axial load and bending about its two main bending axes. It is expected that it will be possible to monitor structural behavior during the fall hurricane season.

## B. North American Aviation Activity (Antenna System)

Detailed monitoring of all phases of the Air Force and Lincoln Laboratory sponsored contracts is continuing. Activity is concentrated on-site, and basic assembly and reflector rigging has been completed. Erection scaffolding teardown is under way.

### 1. Antenna System Assembly

All elements of the antenna system have been assembled and the reflector system has been fine-rigged. Structural instability resulting from environmental thermal changes has made it necessary to undertake fine measurements during the short stable period before sunrise. The last parabolic reflector faceup measurements during one stable period consisted of 402 primary target points. A total number of 1472 painted target points is located on the parabola, and of these 768 are primary points (points seen by the Keuffel and Esser optical probe).

Rigging of 96 reflector panels has been completed in accordance with the NAA (North American Aviation) rigging table. This table contains corrections for measurement errors and structural deflection performance. Observation uncertainty is considered to be  $\pm 0.010$  inch maximum normal to probe line of sight. The observed results are as follows:

Deviation* (inch)	No. of Primary Targets Equal or Less Than Deviation	Percent of 402 Targets
0.010	166	41
0.020	291	72
0.030	369	92
0.037	402	100

\* These are relative to the rigging table only.

2. Antenna System Test

a. Structural Dynamic Test

A short program of transient test by use of quick-release solenoids has been completed for the purpose of checking instrumentation and obtaining gross initial information on natural frequencies.

b. Structural Static Test

Phase II load tests with "skin-on" were completed. The results are being analyzed by both M.I.T. and NAA.

c. Hyperbolic Reflector

The remote control of this assembly has been tested.

3. Engineering

a. Structural

A study has been initiated to determine the effects of increasing the RF box installed weight from 6000 to about 7500 pounds.

Results from the transient tests (Sec. VII-B-2-a) indicate the necessity of stiffening the side ballast structure. Design for this has been started.

b. General

On-site operations in direct support of antenna system electrical and hydraulic tests have been initiated.